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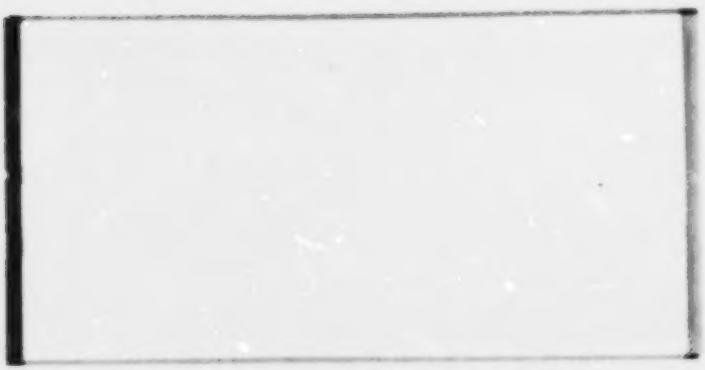

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RESPONSES OF FISH COMMON TO THE ATIKOKAN LAKES AREA TO VARIOUS DETERRENT DEVICES

Report No 84-146-K

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ABSTRACT

Laboratory investigations simulating the Atikokan GS intake design were conducted on the effectiveness of air bubbles, a rope net barrier, light (red), and a pneumatic popper as deterrents for yellow perch (Perca flavescens), and white sucker (Catostomus commersoni). In the low level light tests on perch, all deterrents with the exception of the rope net barrier were effective in repelling fish. Air bubbles alone and red light alone averaged over 84% in effectiveness whereas the rope net alone reduced fish passage by only 42%. Effectiveness of a deterrent generally increased when used in association with another deterrent. Total exclusion (100% effectiveness) occurred when a combined air bubble/rope net scheme was illuminated with red light. This exclusion scheme was also effective (89%) in preventing perch passage in the night tests. In field tests conducted at Lennox GS, a single pneumatic popper was also successful in repelling yellow perch. A rope net barrier alone or combined with red light appears to be the most promising deterrent for white sucker in daytime. No deterrent was found to be effective at night. Further research involving other species common to the Atikokan lakes area is recommended.

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To Dr. W.R. Effer
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RESPONSES OF FISH COMMON TO THE ATIKOKAN LAKES AREA TO VARIOUS DETERRENT DEVICES

INTRODUCTION

A fish deterrent device is required on the intake structure at Atikokan TGS to effectively prevent fish entry. Behavioural barriers have considerable potential as protection devices since they rely on the avoidance responses of fish themselves. They are preferred over mechanical systems since they have no apparent negative impact on fish and are relatively inexpensive. Although a rope net barrier used alone has proven effective in both laboratory and field tests for Great Lakes species such as alewife (Alosa pseudoharengus) and smelt (Osmerus mordax, OHRDR 81-190-K, OHRDR 83-405-K), this barrier has not been tested for species representative of the Atikokan lakes area (except yellow perch, OHRDR 83-351-K). Because of the diverse ecology of major fish species found at Atikokan TGS, it is unlikely that a single behavioural deterrent will exclude all species. A combination of deterrents (ie a "multi-sensory" approach) may be required to effectively repel most species. As part of the COTC fish impingement program (requested by ES &A work order 820-09910), a study was undertaken to determine the responses of species common in the Atikokan lakes area to various deterrents singly and in combination.

MATERIALS AND METHODS

1. Species Studied

Results of field surveys in the Atikokan lakes area have indicated that the following species are numerically important: walleye (Stizostedion vitreum), pike (Esox lucius), cisco (Coregonus artedii), whitefish (Coregonus clupeaformis), yellow perch (Perca flavescens) and white suckers (Catostomus commersoni) (OHRDR 83-338-K). Generally, these species can be categorized as either pelagic or non-pelagic. Walleye, whitefish and cisco are representative of pelagic types, whereas suckers, pike and perch can be grouped as non-pelagic. In this study,

research concentrated on two non-pelagic species, yellow perch and white suckers. The walleye was preferred as a test species , however, it was not available during the testing period.

2. Types of Deterrents Investigated

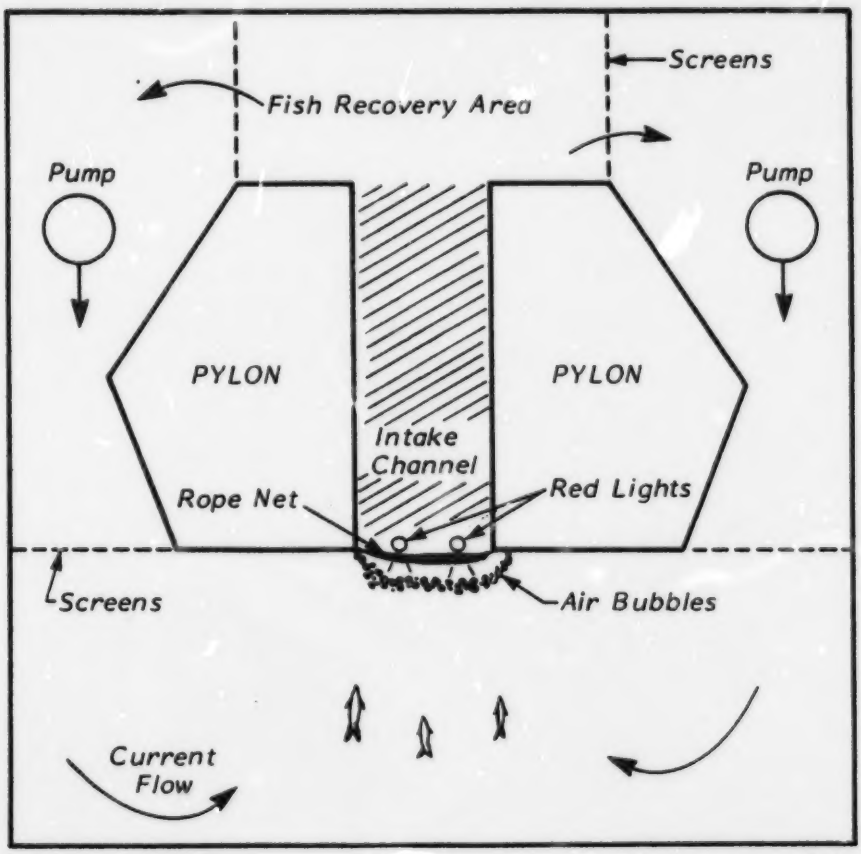
Air bubbles, a rope net barrier, light (red) and pneumatic poppers were tested as fish deterrents. As some barrier types may be effective for particular species but not others, emphasis was also placed on the responses of fish to various combinations of deterrents. Both air bubbles and rope net barriers were selected since these barriers have proven effective in both the laboratory and field for some Great Lakes species (OHRDR 81-190-K, OHRDR 83-405-K, OHRDR 83-351-K. The rope net barrier was similar in design to that used in previous studies (OHRDR 81-190-K, OHRDR 83-351-K), and consisted of 5.0cm vertical and 2.5cm horizontal components, with 20 cm x 20 cm openings. Bubbles were created using a " bio-weve" diffuser hose which has previously been used in laboratory tests (OHRDR 83-142-K). The wand was placed approximately 1.0m in front of the intake opening to compensate for the bubble curtain being deflected by current flow. A constant red light source (600-750nm) was used to illuminate the air bubble and rope net barriers. Red light is the least likely to attract fish, as laboratory tests have indicated some avoidance (OHRDR 78-516-K), and due to rapid attenuation of red light in water, far-field attraction should be avoided. At Atikokan TGS, the area to be illuminated (3.6m diameter intake opening) is quite small. Deterrents to be evaluated were placed on or in front of the intake.

Research on pneumatic poppers, although limited, has been encouraging (Schuler and Larson 1975, Larson, pers comm). Preliminary work conducted at Long Island, New York also suggested that additional studies using pneumatic poppers were warranted (Holsapple, pers comm).

3. Experimental Design

Laboratory Tests

Experiments were conducted in a modified square (8.0m x 8.0m) concrete tank (Figure 1). Depth of the tank was approximately 1.8m. Two concrete pylons were placed in the tank creating an intake channel of approximately 3.0m in length. The intake configuration was approximately square (1.2m x 1.5m), and was similar to that proposed for Atikokan TGS at a scale of approximately 1:3. A 6.4 HP Flygt submersible pump was positioned beside each pylon, and current was directed towards the intake area. Current velocities measured at the intake opening averaged approximately 19cm/s, and were representative of those expected at Atikokan TGS. Velocities varied vertically in the water column



Scale: 1cm = 0.4m

FIGURE 1

INTAKE TEST FACILITY
(OVERHEAD VIEW)

(14-25cm/s), and were slightly higher near the bottom. Tests were conducted under simulated day (<10 lux, <0.2 uE/m^2/s) and night (total darkness) conditions. Light was not measurable in these dark tests. Red light intensities, measured with a Photometer/Quantum meter (Lambda L1- 185), were approximately 200 lux (0.4 uE/m^2/s) at the intake entrance. Light levels estimated 1 and 3 m from the intake were approximately 20 lux (0.4 uE/m^2/s), and 1 lux (0.02 uE/m^2/s), respectively. Because of technical difficulties with the light meter, quantum measurements (uE/m^2/s) were estimated from photometric measurements (lux, see Lambda manual 1983). In the perch tests, the size of the forebay area was reduced approximately 40% with screening (not shown in Figure 1) to prevent fish from holding position in eddies at the edges of the tank. This modification resulted in an increase of fish movement towards the intake channel. Current direction was not affected.

In laboratory tests, the responses of both yellow perch and white suckers to air bubbles, a rope net, red light (600-750 nm), and various combinations of these deterrents were determined (Table 1). The combinations selected were dependent on initial test results obtained for each individual deterrent. For example, in the white sucker tests, red light was combined with a rope net barrier since the rope net barrier appeared to offer the best performance for a single deterrent.

Low level light tests were conducted from 0930 to 1400, and dark tests were conducted at night (1700-2400). Fish to be tested were allowed to acclimate at least 24hr in the experimental tank. Twenty suckers were used in each test whereas in the perch tests sixty fish were used. Four replicates were conducted for each barrier (except red light alone in the low level light perch tests where five replicates were performed), and fish responses to each barrier(s) were categorized as follows:

(i) Number of fish passing through the intake opening over the one hour monitoring period. (In the night tests, it was only feasible to record fish captures at 15 minute intervals or a total of four observations over the one hour monitoring period). The number of fish passing through the barrier in both day and night tests was expressed as a per cent reduction (or effectiveness) relative to the number of fish passages in corresponding control tests (ie absence of barrier).

(ii) Number of encounters 30 and 60cm from the barrier. These estimates refer to the number of fish which approached, and passed over each distance line. These data were only obtained in the low level light tests. Similar to passage results, estimates were determined over a one hour monitoring period.

Control tests were conducted by monitoring fish passages and encounters (30,and 60cm) in the experimental tank in the absence of a deterrent. These tests were also one hour in duration, and were conducted under both low level light (<10 lux) and in total darkness. With the exception of the low level light perch tests,

TABLE 1

SUMMARY OF EXPERIMENTAL DESIGN

Fish Tested	Laboratory /Field	Time/ of Day	Deterrent Tested	Combinations Tested
Yellow Perch	Laboratory	Day	Control Rope Net (RN) Air Bubbles (AB) Red Light (RL)	AB/RN AB/RN/RL
		Night	Control Rope Net Air Bubbles Red Light	AB/RN/RL
	Field	Day	Pneumatic Popper	-
		Night	Pneumatic Popper	-
White Sucker	Laboratory	Day	Control Rope Net Air Bubbles Red Lights	RN/RL
		Night	Control Rope Net Air Bubbles Red Light	RN/RL

four controls were conducted. Nine control tests were conducted in the perch tests because of observed variability in fish movement through the intake opening. High variability in other experiments involving yellow perch has also been observed (OHRDR 83-351K). Raw data are given in Appendices A and B.

Pneumatic poppers were not a feasible option to be evaluated in the lab because of sound reverberation in the tank (ESEERCO 1984, draft report). Consequently, experiments involving pneumatic poppers as a deterrent were conducted in the field (Table 1). Tests were conducted on only yellow perch.

Field Studies

The evaluation of a pneumatic popper as a fish deterrent was conducted in the forebay of Lennox GS. Since the station is not operational, the test species, yellow perch, were introduced. For this reason, the Lennox GS forebay offered a unique test site since the responses of yellow perch to a popper could be determined without influence from other species. Approximately 1000 fish (10-20cm) were collected in the nearby Bay of Quinte using 1.2m trap nets, and placed in the Lennox GS forebay. Fish were allowed to acclimate several days in the forebay prior to testing. The in-line pressure used in these tests was 4650 psi. The popping rate was 20 pops/min.

An acoustic fish census system (OHRDR C79-87K) was used to assess the extent of fish repulsion to the pneumatic popper. At Lennox GS, the transducer was fixed near the east forebay wall, and directed towards the rock cliffs near tempering pump #1 (not operating), a distance of approximately 28m. A single popper was placed at a 3m depth near tempering pump #1. At this location it was observed that fish showed a strong preference for the rock cliffs. There was no current in the forebay. For a more complete description of the study area and the experimental set-up consult ESEERCO (1984, draft report).

Experiments consisted of 20 minute tests in which the number and distribution of echoes were estimated at intervals of 0-5, 5-9, 9-13, 13-17, 17-21, 21-28m from an operating popper. One replicate was conducted during the day and at night. The experimental trial was preceded and followed immediately by control tests (ie a total of two controls) in which the number of echoes were recorded over 20 minute periods. Information obtained 0-5m from the operating popper was not used because of bubble interference from the popper. In this area, echoes created by fish and air bubbles could not be distinguished.

Data collected from both the laboratory and field were analyzed using analysis of variance. Data were log transformed to satisfy assumptions of the analysis of variance. If the F- statistic was significant ($p<0.05$), cell means were compared using the Student-Neumann-Keuls procedure.

RESULTS

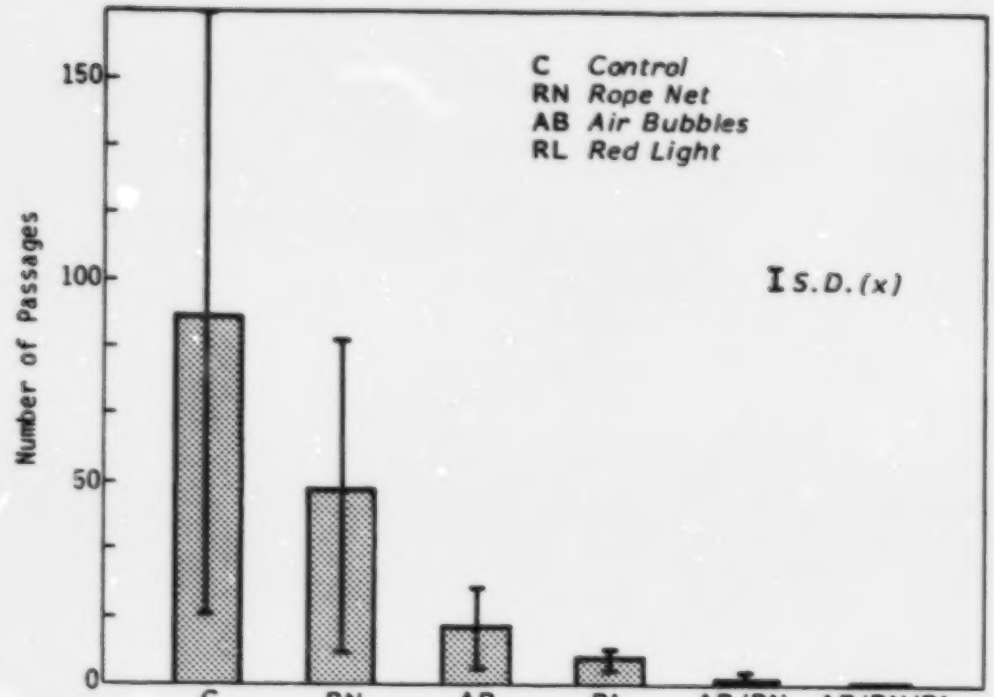
1. Yellow Perch

Laboratory Tests

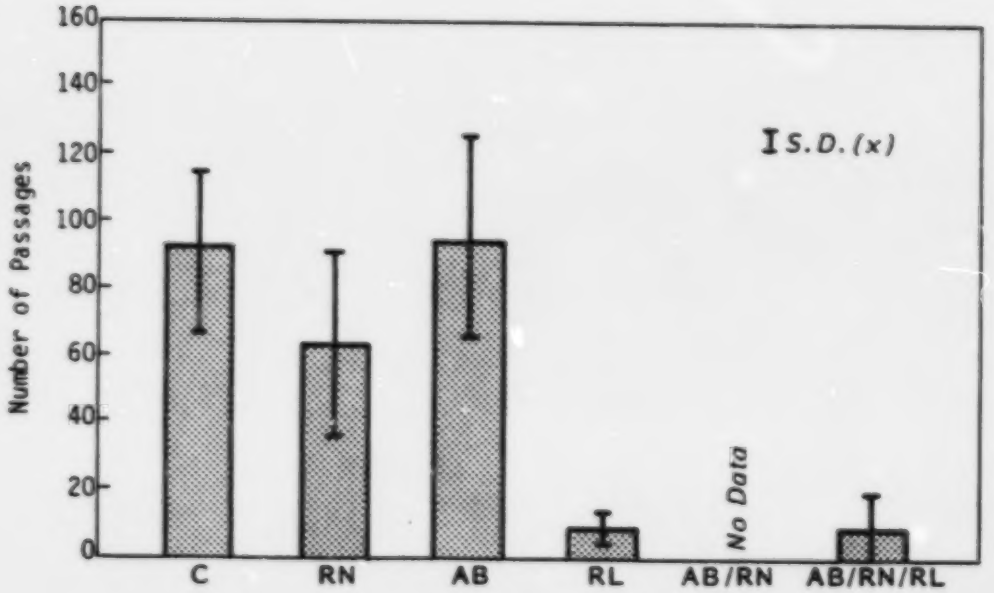
In the low level light tests, all deterrents with the exception of the rope net barrier were effective in reducing the number of perch passages relative to control tests (Figure 2, Table 2). Air bubbles alone, and red light alone averaged over 84% effectiveness which was found to be statistically significant when compared to corresponding control conditions (Table 3). The rope net alone was not very effective as a deterrent, and reduced fish passage by only 42.7% (not statistically different from control, Table 3). However, when air bubbles were combined with the rope net barrier as a "multi-sensory" system, effectiveness increased to 97%. Passage results for this combined barrier were also less variable than observed in control tests or when deterrents were used alone. Total exclusion (100%) occurred when the air bubble/rope net barrier was illuminated with red light.

The encounter data (30cm, 60cm from intake) showed similar trends as observed with the passage results (Table 2). Few perch actually approached the intake area when either red light or air bubbles were used alone or combined with other deterrents. Fish showed an obvious avoidance response to these systems as there were reductions of over 90% in the number of encounters observed compared to control tests. A high number of encounters, however, was observed with the rope net barrier placed in front of the intake. The rope net barrier appeared ineffective in reducing the number of fish encounters relative to control tests. Fish totally avoided the intake area (no encounters) when a combined air bubble/rope net barrier was illuminated with red light.

In the night simulated tests, effectiveness of both air bubbles alone and the rope net barrier alone was reduced (Figure 2, Table 2). With a rope net barrier, effectiveness was reduced from approximately 42% in the day tests to only 26% in the night tests. The air bubble barrier was totally ineffective in the absence of light, although it was quite effective in the day tests (84.9%). These results suggest that illumination is required to increase the effectiveness of both barriers in darkness or when visibility is reduced. When red light was added to these systems effectiveness increased to approximately 89%. There were significantly fewer fish passing through this barrier system relative to passages which occurred in the controls (Table 3). Red light alone also effectively prevented fish passage, averaging approximately 91% effectiveness (Tables 2,3).



(a) LOW LEVEL LIGHT



(b) DARKNESS

FIGURE 2

MEAN NUMBER OF YELLOW PERCH PASSAGES
FOR VARIOUS DETERRENTS

TABLE 2

YELLOW PERCH PASSAGE AND ENCOUNTER DATA

Light Condition	Treatment	PASSAGE DATA			ENCOUNTER DATA			
					30 cm From Intake		60 cm From Intake	
		Mean No of Passages (S.D. (x))	Range	% Reduction From Control	Mean No of Encounters (S.D. (x))	% Reduction From Control	Mean No of Encounters (S.D. (x))	% Reduction From Control
DAY (<10 lux, <0.2 dØ/m ^{2}/s)	Control	85.9 (79.7)	9-251	-	150.0 (75.1)	-	152.0 (78.5)	-
	Rope Net Alone	49.2 (40.5)	7-101	42.7	60.2 (54.2)	59.9	60.2 (58.2)	60.4
	Air Bubbles Alone	13.0 (9.7)	3-24	84.9	14.2 (8.9)	90.5	15.0 (8.5)	90.1
	Red Light Alone	9.4 (0.8)	1-20	89.0	9.8 (8.8)	93.5	10.6 (10.2)	93.0
	Air Bubbles/ Rope Net	2.5 (1.7)	1-5	97.0	3.5 (1.9)	97.7	4.5 (2.1)	97.0
	Air Bubbles/ Rope Net/ Red Light	0 (0)	0	100.0	0 (0)	100.0	0 (0)	100.0
NIGHT (<1 lux, <0.01 dØ/m ^{2}/s)	Control	87.5 (25.9)	57-120	-	-			
	Air Bubbles Alone	93.0 (30.7)	66-137	-6.0	-			
	Rope Net Alone	64.7 (33.6)	41-102	26.0	-			
	Red Light Alone	7.5 (4.0)	4-11	91.4	-			
	Air Bubbles/ Rope Net/ Red Light	9.5 (12.4)	2-28	89.1	-			

Table 3.
Multiple Range Test Comparing The Effectiveness Of Deterrents In Reducing Yellow Perch Passage

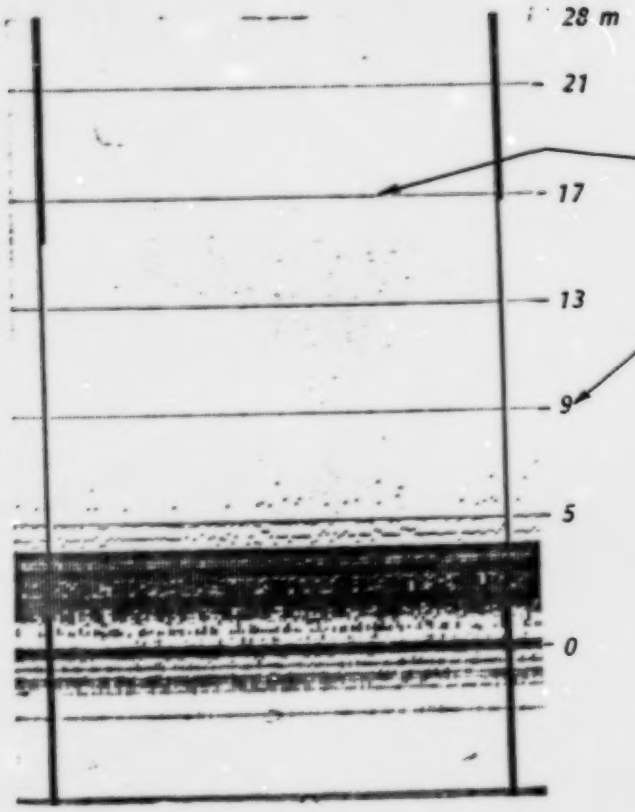
	F-value	Multiple range Test on No. of Passages*					
Day	14.4**	AB/RN/RL	AB/RN	RL	AB	RN	CON
No. of Passages		0	2.5	9.4	13.0	49.2	85.9
Night	18.4**	RL	AB/RN/RL	RN	CON	AB	
No. of Passages		7.5	9.5	64.7	87.5	93.0	

* AB- air bubbles
RN- rope net
RL- red light
CON- control
** sig at $p<0.05$

Field Tests

(i). General Behaviour

Introduced yellow perch showed a definite preference for the rock cliffs (including the tempering pump area) in the Lennox GS forebay where they were released. This was confirmed by visual observation. Fish were not observed to swim in the open water. During control tests (popper not operating), few fish were recorded beyond 5m from these cliffs during the day or at night (Figure 3). This was not unexpected since this species generally prefers areas that provide some cover. The popper was placed at the rock cliffs at a 3m depth. When the popper was operating, fish immediately left the preferred area and retreated towards the open water up to 13m away from the operating popper (Figure 3; ESEERCO,1984 draft report). The output of the transducer illustrated the movement of fish away from the popper (ie an avoidance response). Fish tended to concentrate in a narrow band (2-3m wide) approximately 9-13m from the sound source. Although

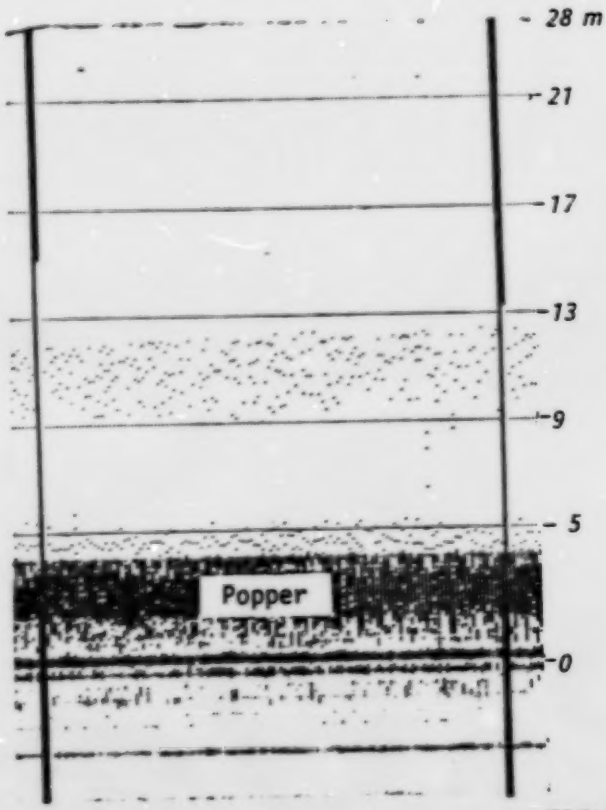


Portion of echogram of a control test (no popper) conducted during the day.

Few fish echoes were recorded in the open water column.

Perch preferred location near rock cliffs.

Horizontal distance.



Portion of echogram of a experimental test (popper on) conducted during the day. With the popper operating fish retreated towards the open water up to 13 m away from the popper.

Area where air bubbles and fish could not be distinguished

FIGURE 3

VISICORDER OUTPUT OF THE DISTRIBUTION OF FISH ECHOES DURING CONTROL AND EXPERIMENTAL TESTS

acoustic pressure measurements were not made at Lennox, it is expected that acoustic pressures would be similar to those recorded at Nanticoke GS (ESEERCO,1984 draft report). This suggests that perch did not display an avoidance response at pressures less than 3.5 kPa (0.5 psi). When the popper was turned off, fish gradually returned to the rock cliffs.

(ii). Poppers

In these tests, no external stimuli were used to attract fish back towards the rock cliffs after an avoidance of the popper occurred. During the initial control tests (C1), which preceded the popper test, fish were present along the rock cliffs area and could not be detected by sonar. Few fish were observed in the open water 5-28m away from the rock cliffs (Figure 4). With the popper operating in both day and night tests, there were significant increases in the number of fish echoes observed at the 5-9m and 9-13m distance intervals relative to control conditions. The increased number in the experimental phase (after 20 minutes of popper operation) does not indicate attraction, but rather the number of fish moving away from the rock cliffs (ie their preferred area) towards the open water. The higher than expected number of echoes in the second control (C2) test conducted immediately after the popper was turned off was attributed to fish not returning immediately to the rock cliffs.

2. White Suckers

Laboratory Tests

In the low level light tests, the rope net barrier alone or combined with red light significantly reduced the number of fish passages relative to the number of passages in control tests (Figure 5, Tables 4,5). Mean effectiveness of the rope net alone and combined with red light averaged approximately 75% and 83%, respectively. Differences in effectiveness between the rope net alone and combined with red light were not statistically significant (Table 5). Both air bubbles alone and red light alone did not appear to be effective deterrents. No difference was noted in fish passages compared to the control tests. A combined air bubble/rope net barrier was approximately 53% effective (Table 4). This reduction was not significant relative to control tests (Table 5).

Generally, deterrents did not significantly reduce passage in the night tests (Tables 4 and 5). The results obtained were highly variable with the rope net showing a mean reduction of approximately 60% (ranging from 47-77%), and air bubbles 22% (range 9-31%). Combinations of deterrents did not enhance the results.

The encounter data indicated that no deterrent was effective in reducing the number of fish actually approaching the intake in the low level light tests (Table 4).

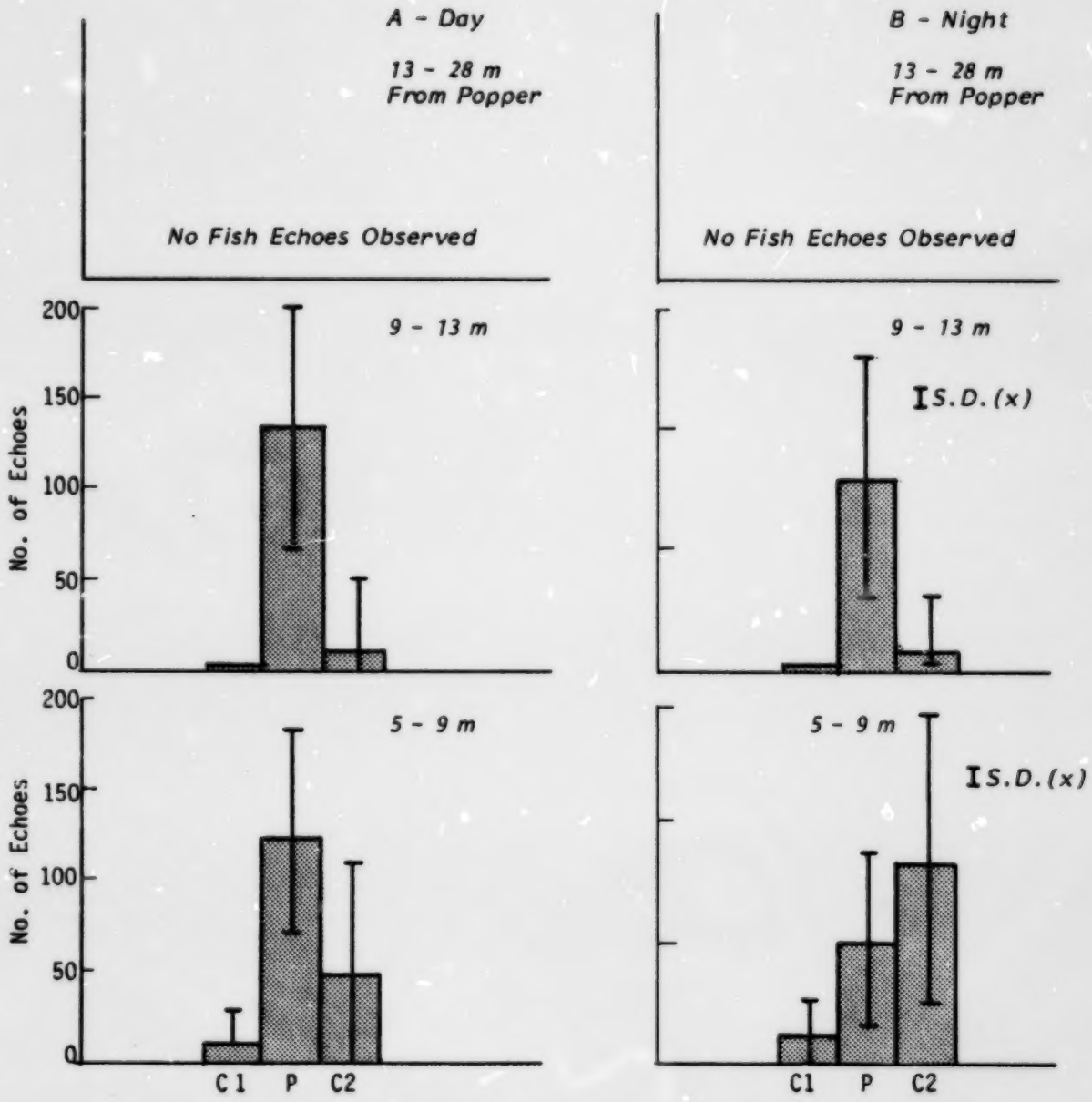
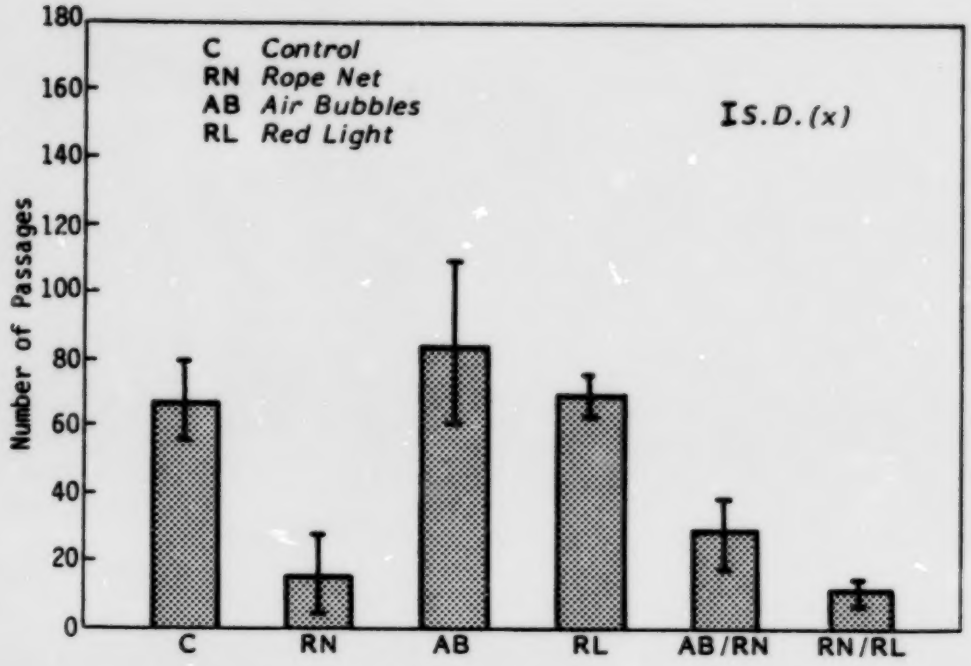
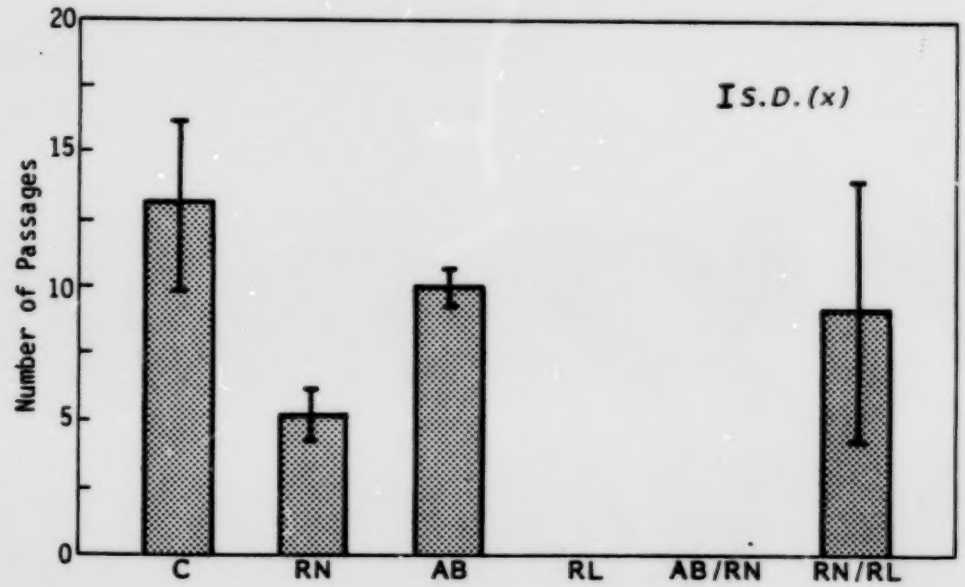


FIGURE 4

MEAN NUMBER OF FISH ECHOES RECORDED IN CONTROL (C1, C2) AND EXPERIMENTAL (P) TESTS DURING DAY AND NIGHT PERIODS - NO STIMULUS



(a) LOW LEVEL LIGHT



(b) DARKNESS

FIGURE 5

MEAN NUMBER OF WHITE SUCKER PASSAGES FOR VARIOUS DETERRENTS

TABLE 4

WHITE SUCKER PASSAGE AND ENCOUNTER DATA

Light Condition	Treatment	PASSAGE DATA			ENCOUNTER DATA			
					30 cm From Intake		60 cm From Intake	
		Mean No of Passages (S.D. (x))	Range	% Reduction From Control	Mean No of Encounters (S.D. (X))	% Reduction From Control	Mean No of Encounters (S.D. (x))	% Reduction From Control
DAY (<10 lux, <0.2μE/m²/s)	Control	66.2 (14.0)	59-86	-	72.2 (14.4)	-	79.2 (15.7)	-
	Rope Net Alone	16.5 (14.1)	2-33	75.1	39.0 (34.3)	45.9	89.2 (33.1)	-12.6
	Air Bubbles Alone	89.2 (25.6)	58-114	-34.0	-	-	-	-
	Red Light	70.5 (4.1)	67-75	- 6.4	79.5 (4.2)	-10.1	94.0 (4.2)	-18.7
	Air Bubbles/ Rope Net	30.7 (11.3)	19-45	53.4	-	-	-	-
	Rope Net/ Red Light	11.2 (5.4)	8-18	83.0	63.0 (20.5)	12.2	79.2 (23.9)	0.0
NIGHT (<1 lux, <0.01μE/m²/s)	Control	13.2	9-16	-	-	-	-	-
	Rope Net Alone	5.2 (1.7)	3-7	60.4	-	-	-	-
	Air Bubbles Alone	10.2 (1.2)	9-12	22.6	-	-	-	-
	Rope Net/ Red Light	8.7 (4.9)	8-13	33.9	-	-	-	-

Table 5.
Multiple Range Test Comparing The Effectiveness Of Deterrents In Reducing White Sucker Passage

	F-value	Multiple range on No. of Passages*					
Day	12.1 **	RL/RN	RN	AB/RN	CON	RL	AB
No. of Passages		11.2	16.5	30.7	66.2	70.5	89.2
Night	3.2	(not significant)					

* RL- red light
AB- air bubbles
RN- rope net
CON- control
** sig at $p<0.05$

DISCUSSION

Yellow perch were observed to display an avoidance response to red light in both simulated day and night tests. Red lights were found to reduce passage by 89% during the day and 91% at night compared to passages under control conditions. These results were consistent with those reported earlier for yellow perch in tests conducted in small tanks (1.2m diameter) in the absence of current (OHRDR 78-516K). Similarly, Hadderingh (1982) reported that yellow perch showed a strong avoidance of light, and a system based on high intensity light was effective in preventing perch entry into the Bergum plant intake. Red light had no marked effect on the behaviour of white sucker. It is not known how other species common to the Atikokan lakes area, such as walleye, will respond to this light source. However, it is expected that this latter species will be sensitive to light.

Pneumatic poppers appeared effective as a deterrent for yellow perch. At Lennox, yellow perch were moved approximately 9-13m from their preferred location along the forebay wall when the popper was operating during the day and at night. Avoidance of

the popper has been found to persist even when both food and light attraction stimuli were used to lure fish back towards the popper (ESEERCO, 1984 draft report). Also, in that study, no acclimation or behavioural adaptation to the popper was observed over a 7h period.

Laboratory results for yellow perch indicated that effectiveness of a deterrent was increased when used in combination with other deterrents. This was especially evident in the low level light tests which showed that effectiveness of either rope net (42%) or air bubble (85%) barriers was increased when barriers were combined (97%). Total exclusion occurred when this barrier combination was illuminated with red light. It appears that by combining barriers, systems can be made more effective as fish deterrents. In another study, we have also found that combining systems can improve the effectiveness of a system for pelagic species (ESEERCO,1984 draft report). For alewife, the effectiveness of a rope net barrier (50-80%) was increased (to 98%) when combined with pneumatic poppers.

An estimate of effectiveness was calculated for deterrents over both day and night periods. For yellow perch, the combined air bubble/rope net barrier illuminated with red light was the most effective perch excluder, averaging 94.5% in effectiveness, followed by red light alone (90.2%), air bubbles alone (39.4%) and a rope net barrier alone (34.2%). For white suckers, the rope net alone averaged 67.7% over the day and night periods. The rope net barrier illuminated with red light averaged approximately 58% effective.

Pneumatic poppers alone, red light alone, or red light combined with air bubbles and a rope net barrier all show promise in an exclusion scheme for yellow perch. Although tests were limited with white suckers, no deterrent was found to be promising at night; the rope net alone or combined with red light appears to be the only promising deterrent evaluated to date in daytime. Still, it is expected that suckers will not be attracted to these other systems.

Although a behavioural system involving one or more deterrents does show promise for application at Atikokan TGS, some species of concern (walleye, pike) should also be tested.

SUMMARY

1. The responses of yellow perch and white sucker to air bubbles, a rope net barrier, light (red), and a pneumatic popper were investigated.

2. For yellow perch, all deterrents with the exception of the rope net barrier were effective in reducing fish passage in the low level light tests. Generally, effectiveness of a deterrent was increased when used in combination with other deterrents.

Total exclusion was achieved with an air bubble/rope net system illuminated with red light in daytime. This scheme also effectively reduced perch passage in the night tests.

3. Although tests were limited, a rope net alone or combined with red light appears to be the most promising deterrent for reducing white sucker passage during daylight only.

4. Behavioural schemes show promise for application at Atikokan TGS; however, the other key species (walleye, pike) should be tested.

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APPENDIX A

FISH PASSAGE DATA

1. YELLOW PERCH - Number of Fish Passages

(a) Low Level Light Tests

Control	251 9	126 124	113 24	95 22	9
Air Bubbles	24	18	3	7	
Rope Net	7	101	30	59	
Air Bubbles/Rope Net	2	5	1	2	
Red Lights (2)	20	4	6	1	16
Air Bubbles/ Rope Net/Red Light	0	0	0	0	

(b) Night Tests

Control	90	120	57	83
Rope Net	102	84	32	41
Air Bubbles	66	87	82	137
Red Light	11	4	11	4
Air Bubbles/Rope Net /Red Light	28	2	6	2

2. WHITE SUCKER - Number of Fish Passages

(a) Low Level Light Tests

Control	54	86	66	59
Air Bubbles	58	114	79	106
Rope Net	8	2	23	33
Red Light (2)	67	73	67	75
Air Bubbles/Rope Net	19	45	34	25
Red Light/Rope Net	8	6	18	13

(b) Night Tests

Control	13	16	15	9
Air Bubbles	9	10	12	10
Rope Net	3	5	6	7
Rope Net / Red Light	12	2	8	13

APPENDIX B

FISH ENCOUNTER DATA (LOW LEVEL LIGHT)

1. YELLOW PERCH

(a) 30 cm from Intake

Control	261 9	129 22	113 126	97 26	9
Air Bubbles	25	18	5	9	
Rope Net	21	139	28	53	
Air Bubble/ Rope Net	2	6	2	4	
Red Lights (2)	22	4	6	1	16
Air Bubbles/Rope Net /Red Light	0	0	0	0	

(b) 60 cm from Intake

Control	268 10	130 22	113 128	97 31	10
Air Bubbles	25	18	4	12	
Rope Net	31	147	24	39	
Air Bubbles/Rope Net	2	7	4	5	
Red Lights (2)	26	4	6	1	16
Air Bubbles/Rope Net /Red Light	0	0	0	0	

2. WHITE SUCKER

(a) 30 cm from Intake

Control	58	92	72	67
Rope Net	87	39	9	21
Red Lights (2)	75	82	77	84
Red Light/Rope Net	74	61	75	82

APPENDIX B ... cont'd

(b) 60 cm from Intake

Control	65	101	80	71
Rope Net	106	55	69	127
Red Lights (2)	90	91	99	96
Red Light/Rope Net	94	78	46	99